

-222-

## CLAIMS

1. A virtual viewpoint image generation method comprising:
- 5           a step of obtaining plural images of an object taken by plural cameras;
- a step of determining a virtual viewpoint that is a position from which the object is viewed; and
- 10           a step of generating a virtual viewpoint image that is an image of the object viewed from the virtual viewpoint based on the obtained images of the object,
- the step of generating the virtual
- 15   viewpoint image comprising:
- a step 1 of setting projection planes having a multi-layered structure;
- a step 2 of obtaining each corresponding point, on the images of the object, corresponding to
- 20   a projection point of a projection plane;
- a step 3 of determining color information or brightness information of each projection point based on color information or brightness information of corresponding points;
- 25           a step of calculating, for each of the projection points overlapping when viewed from a reference viewpoint in a space, a degree of probability that the object exists at a distance corresponding to a position of the projection point
- 30   based on a degree of correlation of the corresponding points or neighborhoods of the corresponding points;
- a step 5 of performing mixing processing on color information or brightness information of
- 35   reference points overlapping when viewed from the virtual viewpoint according to the degree of probability of existence of the object so as to

-223-

determine color information or brightness  
information of each pixel of the virtual viewpoint  
image; and

5 a step 6 of repeating steps from the step  
1 to the steps 5 for every point corresponding to  
pixels of the virtual viewpoint image.

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2. The virtual viewpoint image generation  
method as claimed in claim 1, the step 3 comprising:  
mixing the color information or the  
brightness information of the corresponding points  
15 or selecting the color information or the brightness  
information of one corresponding point from the  
color information or the brightness information of  
the corresponding points.

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3. The virtual viewpoint image generation  
method as claimed in claim 1 or 2, the step 4 or the  
25 step 5 comprising:

a step of setting, in each reference point  
on the projection plane, transparency having plural  
gradations from transparent to opaque by converting  
the degree of probability that the object exists;  
30 and

the step 5 comprising:  
performing the mixing processing according  
to the transparency instead of the degree of  
probability that the object exists.

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-224-

4. The virtual viewpoint image generation method as claimed in claim 3, the mixing processing of the step 5 comprising:

5           processing projection points successively from a projection point far from the virtual viewpoint to a projection point near the virtual viewpoint,

          wherein color information or brightness  
10 information obtained by the mixing processing up to a projection point is obtained by calculating interior division between color information or brightness information at the projection point and  
15 by the mixing processing up to a previous projection point in a ratio according to the transparency.

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5. The virtual viewpoint image generation method as claimed in any one of claims 1-4, wherein:

          projection planes specific to each camera  
taking each image of the object are set in the step  
25 1;

          the color information or the brightness  
information of the step 3 are determined only by  
using color information or brightness information of  
the corresponding points of the images of the object  
30 taken by the plural cameras;

          the degree of probability that the object  
exists in step 4 is calculated using, as the  
reference viewpoint, a viewpoint of the camera  
specific to the projection plane to which the  
35 projection point belongs; and

          correction is performed based on position  
relationship between the virtual viewpoint and each

-225-

reference viewpoint in the mixing processing of the color information or the brightness information.

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6. A virtual viewpoint image generation apparatus comprising:

an object image obtaining means for  
10 obtaining plural images of an object taken by plural cameras;

a virtual viewpoint determination means  
for determining a virtual viewpoint that is a  
position from which the object is viewed; and  
15 an image generation means for generating a virtual viewpoint image that is an image of the object viewed from the virtual viewpoint based on the obtained images of the object,

the image generation means comprising:  
20 a projection plane determination means for determining projection planes having a multi-layered structure;

a reference viewpoint determination means  
for determining a position of the reference  
25 viewpoint;

a texture array keeping means for keeping  
an array of texture images to be mapped to the  
projection planes;

a corresponding point matching processing  
30 means for associating parts, in the images of the object, on which the same region of the object appears with each other;

a color information determination means  
for determining color information or brightness  
35 information in the array of the texture images by performing mixing processing on the images of the object;

-226-

an existence probability information determination means for calculating a degree of probability that the object exists at a distance corresponding to a position of the projection point  
5 in the array of the texture images based on the processing result of the corresponding point matching processing means;

a rendering means for rendering the projection planes viewed from the virtual viewpoint  
10 based on the color information or the brightness information determined by the color information determination means and the existence probability determined by the existence probability determination means.

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7. The virtual viewpoint image generation  
20 apparatus as claimed in claim 6, the existence probability information determination means comprising:

a means for setting, in each reference point on the projection plane, transparency having  
25 plural gradations from transparent to opaque by converting the degree of possibility that the object exists;

wherein the rendering means performs rendering using the transparency instead of the  
30 degree of possibility that the object exists.

35 8. The virtual viewpoint image generation apparatus as claimed in claim 7, the rendering means comprising:

-227-

a means for processing projection points successively from a projection point far from the virtual viewpoint to a projection point near the virtual viewpoint,

5                wherein color information or brightness information obtained by the mixing processing up to a projection point is obtained by calculating interior division between color information or  
10                color information or brightness information obtained by the mixing processing up to a previous projection point in a ratio according to the transparency.

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9. The virtual viewpoint image generation apparatus as claimed in any one of claims 6-8, wherein:

20                the projection plane determination means determines projection planes specific to each camera taking each image of the object;

                 the color information determination means determines the color information or the brightness  
25                information only by using color information or brightness information of the corresponding points of the images of the object taken by the plural cameras;

                 the existence probability information  
30                determination means calculates the degree of probability that the object exists by using, as the reference viewpoint, a viewpoint of the camera specific to the projection plane to which the projection point belongs; and

35                the rendering means includes a means for performing correction based on position relationship between the virtual viewpoint and each reference

-228-

viewpoint.

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10. A virtual viewpoint image generation program causing a computer to perform:

a step of obtaining plural images of an object taken by plural cameras;

10 a step of determining a virtual viewpoint that is a position from which the object is viewed; and

15 a step of generating a virtual viewpoint image that is an image of the object viewed from the virtual viewpoint based on the obtained images of the object,

the step of generating the virtual viewpoint image comprising:

20 a step 1 of setting projection planes having a multi-layered structure;

a step 2 of obtaining each corresponding point, on the images of the object, corresponding to a projection point of a projection plane;

25 a step 3 of determining color information or brightness information of each projection point based on color information or brightness information of corresponding points;

30 a step 4 of calculating, for each of the projection points overlapping when viewed from a reference viewpoint in a space, a degree of probability that the object exists at a distance corresponding to a position of the projection point based on a degree of correlation of the corresponding points or neighborhoods of the corresponding points;

35 a step 5 of performing mixing processing on color information or brightness information of

-229-

reference points overlapping when viewed from the virtual viewpoint according to the degree of probability of existence of the object so as to determine color information or brightness

5 information of each pixel of the virtual viewpoint image; and

a step 6 of repeating steps from the step 1 to the steps 5 for every point corresponding to pixels of the virtual viewpoint image.

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11. A computer readable recording medium  
15 storing the virtual viewpoint image generation program as claimed in claim 10.

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12. An image generation method comprising:

a step of obtaining images of an object taken from different viewpoints;

25 a step of obtaining a three-dimensional shape of the object based on the images; and

a step of generating an image of the object viewed from a viewpoint of an observer based on the obtained three-dimensional shape of the  
30 object,

the step of obtaining the three-dimensional shape of the object comprising:

a step of setting projection planes having a multi-layered structure in a virtual three-  
35 dimensional space;

a step of determining a reference viewpoint for obtaining the three-dimensional shape



-230-

of the object;

a step of determining color information or brightness information of projection points that are points on the projection planes based on color  
5 information or brightness information of corresponding points, on the obtained images, corresponding to the projection points;

a step of calculating correlation degrees among corresponding points corresponding to the  
10 projection points;

a step of calculating, for each of the projection points overlapping when viewed from the reference viewpoint, an existence probability that is a probability that the object exists at the  
15 projection point based on the correlation degree of each projection point;

the step of calculating the correlation degree comprising:

a step of preparing plural groups of  
20 camera sets each being a group of some viewpoints selected from the plural viewpoints; and

a step of obtaining the correlation degree from the corresponding points on images included in each camera set,

25 the step of determining the existence probability comprising:

a step of calculating the existence probability based on the correlation degree of each projection point obtained for each camera set; and

30 a step of determining the existence probability of each projection point by performing integrating processing for the existence probability determined for each camera set.

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-231-

13. The image display method as claimed in claim 12, the step of calculating the existence probability based on the correlation degree of each projection point obtained for each camera set

5 comprising:

a step of calculating an evaluation reference value based on the correlation degree of each projection point calculated for each camera set;

10 a step of calculating a distribution function of the existence probability by performing statistical processing on the evaluation reference value of each projection point calculated for each camera set; and

15 a step of determining the existence probability of each projection point based on the distribution function of the existence probability.

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14. The image generation method as claimed in claim 12 or 13, the step of generating the image of the object viewed from the viewpoint of the

25 observer comprising:

mixing color information or brightness information of the projection points overlapping when viewed from the viewpoint of the observer in a ratio of the existence probability to determine  
30 color information or brightness information of each point on the image to be generated so as to generate a two-dimensional image.

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15. The image generation method as

-232-

claimed in claim 12 or 13, the step of generating the image of the object viewed from the viewpoint of the observer comprising:

- a step of setting plural image
- 5 generation planes at positions having different depths when viewed from the viewpoint of the observer; and
- a step of converting the color
- 10 information or brightness information and the existence probability of each projection point into color information or brightness information and a brightness distribution coefficient on each image
- 15 generation plane based on position relationship among projection points overlapping when viewed from the viewpoint of the observer and points on each image generation plane.

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16. An image generation apparatus comprising:

- an object image obtaining means for
- obtaining images of an object taken from different
- 25 viewpoints;
- a three-dimensional shape obtaining means
- for obtaining a three-dimensional shape of the object based on the images; and
- an object image generation means for
- 30 generating an image of the object viewed from a viewpoint of an observer based on the obtained three-dimensional shape of the object,
- the three-dimensional shape obtaining
- means comprising:
- 35 a means for setting projection planes having a multi-layered structure in a virtual three-dimensional space;

-233-

a means for determining a reference viewpoint for obtaining the three-dimensional shape of the object;

5 a means for determining color information or brightness information of projection points that are points on the projection planes based on color information or brightness information of corresponding points, on the obtained images, corresponding to the projection points;

10 a means for calculating correlation degrees among corresponding points corresponding to the projection points;

15 a means for determining, for each of the projection points overlapping when viewed from the reference viewpoint, an existence probability that is a probability that the object exists at the projection point based on the correlation degree of each projection point;

20 the means for calculating the correlation degree comprising:

a means for preparing plural groups of camera sets each being a group of some viewpoints selected from the plural viewpoints; and

25 a means for obtaining the correlation degree from the corresponding points on images included in each camera set,

the means for determining the existence probability comprising:

30 a means for calculating the existence probability based on the correlation degree of each projection point obtained for each camera set; and

35 a means for determining the existence probability of each projection point by performing integrating processing for the existence probability determined for each camera set.

-234-

17. The image generation apparatus as claimed in claim 16, the means for calculating the  
5 existence probability based on the correlation degree of each projection point obtained for each camera set comprising:

a means for calculating an evaluation reference value based on the correlation value of  
10 each projection point calculated for each camera set;

a means for calculating a distribution function of the existence probability by performing statistical processing on the evaluation reference  
15 value of each projection point calculated for each camera set; and

a means for determining the existence probability of each projection point based on the distribution function of the existence probability.  
20

18. The image generation apparatus as claimed in claim 16 or 17, wherein the means for  
25 generating the image of the object viewed from the viewpoint of the observer is a means for:

mixing color information or brightness information of the projection points overlapping  
30 when viewed from the viewpoint of the observer in a ratio of the existence probability to determine color information or brightness information of each point on the image to be generated so as to determine a two-dimensional image.

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-235-

19. The image generation apparatus as claimed in claim 16 or 17, the means for generating the image of the object viewed from the viewpoint of the observer comprising:

- 5 a means for setting plural image generation planes at positions having different depths when viewed from the viewpoint of the observer; and
- 10 a means for converting the color information or brightness information and the existence probability of each projection point into color information or brightness information and a brightness distribution coefficient on each image
- 15 generation plane based on position relationship among projection points overlapping viewed from the viewpoint of the observer and points on the image generation planes.

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20. An image generation program causing a computer to perform:

- 25 a step of obtaining images of an object taken from different viewpoints;
- a step of obtaining a three-dimensional shape of the object based on the images; and
- a step of generating an image of the
- 30 object viewed from a viewpoint of an observer based on the obtained three-dimensional shape of the object,
- the step of obtaining the three-dimensional shape of the object comprising:
- 35 a step of setting projection planes having a multi-layered structure in a virtual three-dimensional space;

-236-

a step of determining a reference viewpoint for obtaining the three-dimensional shape of the object;

5 a step of determining color information or brightness information of projection points that are points on the projection planes based on color information or brightness information of corresponding points, on the obtained images, corresponding to the projection points;

10 a step of calculating correlation degrees among corresponding points corresponding to the projection points;

15 a step of calculating, for each of the projection points overlapping when viewed from the reference viewpoint, an existence probability that is a probability that the object exists at the projection point based on the correlation degree of each projection point;

20 the step of calculating the correlation degree comprising:

a step of preparing plural groups of camera sets each being a group of some viewpoints selected from the plural viewpoints; and

25 a step of obtaining the correlation degree from the corresponding points on images included in each camera set,

the step of determining the existence probability comprising:

30 a step of calculating the existence probability based on the correlation degree of each projection point obtained for each camera set; and

35 a step of determining the existence probability of each projection point by performing integrating processing for the existence probability determined for each camera set.

-237-

21. A computer readable recording medium  
storing the image generation program as claimed in  
5 claim 20.

10 22. An image generation method comprising:  
a step of obtaining images of an object  
taken by changing focusing distance;  
a step of obtaining a virtual viewpoint  
that is a viewpoint from which the object appearing  
15 in the images is viewed;  
a step of obtaining a three-dimensional  
shape of the object based on the images; and  
a step of generating an image of the  
object viewed from the virtual viewpoint based on  
20 the obtained three-dimensional shape of the object,  
the step of obtaining the three-  
dimensional shape of the object comprising:  
a step of setting projection planes having  
a multi-layered structure in a virtual three-  
25 dimensional space;  
a step of determining a reference  
viewpoint for obtaining the three-dimensional shape  
of the object;  
a step of determining color information or  
30 brightness information of projection points, that  
are points on the projection planes, based on color  
information or brightness information of  
corresponding points, on the obtained images,  
corresponding to the projection points;  
35 a step of determining focusing degrees of  
the projection points based on focusing degrees of  
the corresponding points corresponding to the



-238-

projection points;

5 a step of calculating, for each of the projection points overlapping when viewed from the reference viewpoint, an existence probability that is a probability that the object exists at a distance corresponding to a position of the projection point based on the focusing degree of each projection point;

10 the step of generating the image of the object viewed from the virtual viewpoint comprising:  
mixing color information or brightness information of the projection points overlapping when viewed from the virtual viewpoint in a ratio corresponding to the existence probability to  
15 determine color information or brightness information of each point of the image to be generated.

20

23. The image generation method as claimed in claim 22, the step of obtaining the three-dimensional shape of the object or the step of  
25 generating the image of the object viewed from the virtual viewpoint comprising:

a step of setting transparency having plural gradations from transparent to opaque on each projection point based on the existence probability  
30 of the projection points overlapping when viewed from the reference viewpoint or the virtual viewpoint;

the step of generating the image of the object viewed from the virtual viewpoint comprising:  
35 mixing the color information or the brightness information of the projection points overlapping when viewed from the virtual viewpoint

-239-

in a ratio according to the transparency set based on the existence probability so as to determine the color information or brightness information of each point of the image to be generated.

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24. The image generation method as claimed  
10 in claim 23,

the step of generating the image of the  
object viewed from the virtual viewpoint comprising:  
mixing the color information or the  
brightness information for projection points  
15 successively from a projection point far from the  
virtual viewpoint to a projection point near the  
virtual viewpoint,

wherein color information or brightness  
information obtained by the mixing processing up to  
20 a projection point is obtained by calculating  
interior division between color information or  
brightness information at the projection point and  
color information or brightness information obtained  
by the mixing processing up to a previous projection  
25 point in a ratio according to the transparency.

30 25. An image generation apparatus  
comprising:

an object image obtaining means for  
obtaining images of an object taken by changing  
focusing distance;

35 a virtual viewpoint setting means for  
setting a virtual viewpoint that is a viewpoint from  
which the object appearing in the images is viewed;

-240-

a three-dimensional shape obtaining means  
for obtaining a three-dimensional shape of the  
object based on the images; and

5 a rendering means for generating an image  
of the object viewed from the virtual viewpoint  
based on the obtained three-dimensional shape of the  
object,

the three-dimensional shape obtaining  
means comprising:

10 a means for setting projection planes  
having a multi-layered structure in a virtual three-  
dimensional space;

a means for determining a reference  
viewpoint for obtaining the three-dimensional shape  
15 of the object;

a means for determining color information  
or brightness information of projection points, that  
are points on the projection planes, based on color  
information or brightness information of  
20 corresponding points, on the obtained images,  
corresponding to the projection points;

a means for determining focusing degrees  
of the projection points based on focusing degrees  
of the corresponding points corresponding to the  
25 projection points;

a means for determining, for each of the  
projection points overlapping when viewed from the  
reference viewpoint, an existence probability that  
is a probability that the object exists at a  
30 distance corresponding to a position of the  
projection point based on the focusing degree of  
each projection point;

the rendering means comprising:

35 a means for mixing color information or  
brightness information of the projection points  
overlapping when viewed from the virtual viewpoint  
in a ratio corresponding to the existence

-241-

probability to determine color information or brightness information of each point of the image to be generated.

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26. The image generation apparatus as claimed in claim 25, the three-dimensional shape  
10 obtaining means or the rendering means comprising:  
a means for setting transparency having plural gradations from transparent to opaque on each projection point based on the existence probability of the projection points overlapping when viewed  
15 from the reference viewpoint or the virtual viewpoint; and

the rendering means comprising:  
a means for mixing the color information or the brightness information of the projection  
20 points overlapping when viewed from the virtual viewpoint in a ratio according to the transparency set based on the existence probability so as to determine the color information or brightness information of each point of the image to be  
25 generated.

30 27. The image generation apparatus as claimed in claim 26,  
the rendering means comprising:  
a means for mixing the color information or the brightness information for projection points  
35 successively from a projection point far from the virtual viewpoint to a projection point near the virtual viewpoint,

-242-

wherein color information or brightness information obtained by the mixing processing up to a projection point is obtained by calculating interior division between color information or  
5 brightness information at the projection point and color information or brightness information obtained by the mixing processing up to a previous projection point in a ratio according to the transparency.

10

28. An image generation program for causing a computer to perform::  
15 a step of obtaining images of an object taken by changing focusing lengths;  
a step of obtaining a virtual viewpoint that is a viewpoint from which the object appearing in the images is viewed;  
20 a step of obtaining a three-dimensional shape of the object based on the images; and  
a step of generating an image of the object viewed from the virtual viewpoint based on the obtained three-dimensional shape of the object,  
25 the step of obtaining the three-dimensional shape of the object comprising:  
a step of setting projection planes having a multi-layered structure in a virtual three-dimensional space;  
30 a step of determining a reference viewpoint for obtaining the three-dimensional shape of the object;  
a step of determining color information or brightness information of projection points, that  
35 are points on the projection planes, based on color information or brightness information of corresponding points, on the obtained images,

-243-

corresponding to the projection points;

a step of determining focusing degrees of the projection points based on focusing degrees of the corresponding points corresponding to the projection points;

5 a step of calculating, for each of the projection points overlapping when viewed from the reference viewpoint, an existence probability that is a probability that the object exists at a distance corresponding to a position of the projection point based on the focusing degree of each projection point;

10 the step of generating the image of the object viewed from the virtual viewpoint comprising:  
15 mixing color information or brightness information of the projection points overlapping when viewed from the virtual viewpoint in a ratio corresponding to the existence probability to determine color information or brightness  
20 information of each point of the image to be generated.

25

29. A computer readable recording medium storing the image generation program as claimed in claim 28.

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30. An image generation method comprising:  
a step of obtaining images of an object  
35 taken under different conditions;  
a step of obtaining a three-dimensional shape of the object based on the images; and

-244-

a step of generating an image of the object viewed from a viewpoint of an observer based on the obtained three-dimensional shape of the object,

5           the step of obtaining the three-dimensional shape of the object comprising:

a step of setting projection planes having a multi-layered structure in a virtual three-dimensional space;

10           a step of determining a reference viewpoint for obtaining the three-dimensional shape of the object;

a step of determining color information or brightness information of projection points, that  
15           are points on the projection planes, based on color information or brightness information of corresponding points, on the obtained images, corresponding to the projection points;

20           a step of determining, for each of the projection points overlapping when viewed from the reference viewpoint, an existence probability that is a probability that a surface of the object exists at the projection point;

25           the step of determining the existence probability comprising:

a step of calculating an evaluation reference value of each projection point from image information of the corresponding points;

30           a step of performing statistical processing on the evaluation reference value of each projection point; and

a step of calculating the existence probability of each projection point based on the evaluation reference value on which the statistical  
35           processing has been performed.

-245-

31. The image generation method as claimed in claim 30, the step of obtaining the plural images comprising:
- obtaining images by taking the object from different viewpoints;
  - the step of determining the existence probability comprising:
    - a step of obtaining correlation degrees among corresponding points corresponding to the projection points;
    - a step of calculating the evaluation reference value based on the correlation degree of each projection point;
    - a step of performing the statistical processing on the evaluation reference value; and
    - a step of calculating the existence probability of each projection point based on the evaluation reference value on which the statistical processing has been performed.
32. The image generation method as claimed in claim 30, the step of obtaining the plural images comprising:
- obtaining the images of the object taken from a viewpoint by changing focusing distance;
  - the step of determining the existence probability comprising:
    - a step of calculating focusing degrees of the projection points from focusing degrees of the corresponding points corresponding to the projection points;
    - a step of calculating the evaluation



-246-

reference value based on the focusing degree of each projection point;

a step of performing the statistical processing on the evaluation reference value; and

5 a step of calculating the existence probability of each projection point based on the evaluation reference value on which the statistical processing has been performed.

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33. The image generation method as claimed in claim 30, the step of obtaining the plural images comprising:

15 obtaining images of the object taken from plural viewpoints, and images of the object taken from equal to one or more viewpoints among the plural viewpoints by changing focusing distance;

20 the step of determining the existence probability comprising:

a step of obtaining correlation degrees between the projection points and corresponding points on the plural images of different viewpoints;

25 a step of obtaining a first evaluation reference value based on the correlation degrees of each projection point; and

a step of performing the statistical processing on the first evaluation reference value;

30 a step of calculating focusing degrees of the projection points based on focusing degrees of the corresponding points on the images of different focusing distances;

a step of calculating a second evaluation reference value based on the focusing degrees of each projection point; and

35 a step of calculating the existence

-247-

probability of each projection point based on the first evaluation reference value and the second evaluation reference value on which the statistical processing has been performed.

5

34. The image generation method as  
10 claimed in any one of claims 30-33, the step of  
generating the image of the object viewed from the  
viewpoint of the observer comprising:  
mixing color information or brightness  
information of the projection points overlapping  
15 when viewed from the viewpoint of the observer in a  
ratio of the existence probability to determine  
color information or brightness information of each  
point on the image to be generated so as to  
determine a two-dimensional image.

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35. The image generation method as  
25 claimed in any one of claims 30-33, the step of  
generating the image of the object viewed from the  
viewpoint of the observer comprising:  
a step of setting plural image  
generation planes at positions having different  
30 depths when viewed from the viewpoint of the  
observer; and  
a step of converting the color  
information or brightness information and the  
existence probability of each projection point into  
35 color information or brightness information and a  
brightness distribution coefficient on each image  
generation plane based on position relationship

-248-

among projection points overlapping viewed from the viewpoint of the observer and points on the image generation planes.

5

36. An image generation apparatus comprising:

10 an object image obtaining means for obtaining images of an object taken under different conditions;

an object shape obtaining means for obtaining a three-dimensional shape of the object based on the images; and

15 an object image generation means for generating an image of the object viewed from a viewpoint of an observer based on the obtained three-dimensional shape of the object,

20 the object shape obtaining means comprising:

a means for setting projection planes having a multi-layered structure in a virtual three-dimensional space;

25 a means for determining a reference viewpoint for obtaining the three-dimensional shape of the object;

30 a means for determining color information or brightness information of projection points, that are points on the projection planes, based on color information or brightness information of corresponding points, on the obtained images, corresponding to the projection points;

35 a means for determining, for each of the projection points overlapping when viewed from the reference viewpoint, an existence probability that is a probability that a surface of the object exists

-249-

at the projection point;

the means for determining the existence probability comprising:

5 a means for calculating an evaluation reference value of each projection point from image information of the corresponding points;

a means for performing statistical processing on the evaluation reference value of each projection point; and

10 a means for calculating the existence probability of each projection point based on the evaluation reference value on which the statistical processing has been performed.

15

37. The image generation apparatus as claimed in claim 36, wherein the object image

20 obtaining means obtains images of the object taken from different viewpoints;

the means for determining the existence probability comprising:

a means for obtaining correlation degrees

25 among corresponding points corresponding to the projection points;

a means for calculating the evaluation reference value based on the correlation degree of each projection point;

30 a means for performing the statistical processing on the evaluation reference value; and

a means for calculating the existence probability of each projection point based on the evaluation reference value on which the statistical

35 processing has been performed.

-250-

38. The image generation apparatus as claimed in claim 36, wherein the object image  
5 obtaining means obtains the images of the object taken from a viewpoint by changing focusing distance;  
the means for determining the existence probability comprising:  
10 a means for calculating focusing degrees of the projection points from focusing degrees of the corresponding points corresponding to the projection points;  
a means for calculating the evaluation  
15 reference value based on the focusing degree of each projection point;  
a means for performing the statistical processing on the evaluation reference value; and  
a means for calculating the existence  
20 probability of each projection point based on the evaluation reference value on which the statistical processing has been performed.

25

39. The image generation apparatus as claimed in claim 36, wherein the object image  
obtaining means obtains images of the object taken  
30 from plural viewpoints, and images of the object taken from equal to one or more viewpoints among the plural viewpoints by changing focusing distance;  
the means for determining the existence probability comprising:  
35 a means for obtaining correlation degrees between the projection points and corresponding points on the plural images having

-251-

different projection points;

a means for obtaining a first evaluation reference value based on the correlation degrees of each projection point; and

5 a means for performing the statistical processing on the first evaluation reference value;

a means for calculating focusing degrees of the projection points based on focusing degrees of the corresponding points on the images of

10 different focusing distances taken from a viewpoint;

a means for calculating a second evaluation reference value based on the focusing degrees of each projection point; and

15 a means for calculating the existence probability of each projection point based on the first evaluation reference value and the second evaluation reference value on which the statistical processing has been performed.

20

40. The image generation apparatus as claimed in any one of claims 36-39, the means for  
25 generating the image of the object viewed from the viewpoint of the observer comprising:

a means for mixing color information or brightness information of the projection points overlapping when viewed from the viewpoint of the  
30 observer in a ratio of the existence probability to determine color information or brightness information of each point on the image to be generated so as to determine a two-dimensional image.

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-252-

41. The image generation apparatus as claimed in any one of claims 36-39, the means for generating the image of the object viewed from the viewpoint of the observer comprising:

- 5           a means for setting plural image generation planes at positions having different depths when viewed from the viewpoint of the observer; and
- 10           a means for converting the color information or brightness information and the existence probability of each projection point into color information or brightness information and a brightness distribution coefficient on each image
- 15           among projection points overlapping viewed from the viewpoint of the observer and points on the image generation planes.

20

42. An image generation program causing a computer to perform:

- 25           a step of obtaining images of an object taken under different conditions;
- a step of obtaining a three-dimensional shape of the object based on the images; and
- a step of generating an image of the object viewed from a viewpoint of an observer based
- 30           on the obtained three-dimensional shape of the object,
- the step of obtaining the three-dimensional shape of the object comprising:
- a step of setting projection planes having
- 35           a multi-layered structure in a virtual three-dimensional space;
- a step of determining a reference

-253-

viewpoint for obtaining the three-dimensional shape of the object;

5 a step of determining color information or brightness information of projection points, that are points on the projection planes, based on color information or brightness information of corresponding points, on the obtained images, corresponding to the projection points;

10 a step of determining, for each of the projection points overlapping when viewed from the reference viewpoint, an existence probability that is a probability that a surface of the object exists at the projection point;

15 the step of determining the existence probability comprising:

a step of calculating an evaluation reference value of each projection point from image information of the corresponding points;

20 a step of performing statistical processing on the evaluation reference value of each projection point; and

25 a step of calculating the existence probability of each projection point based on the evaluation reference value on which the statistical processing has been performed.

30 43. A computer readable recording medium storing the image generation program as claimed in claim 42.

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44. A three-dimensional image display



-254-

method comprising:

a step of obtaining images of an object  
taken under different conditions;

5 a step of obtaining a three-dimensional  
shape of the object based on the images;

a step of setting a viewpoint position  
from which an observer observes plural image display  
planes existing at different depth positions when  
viewed from the observer;

10 a step of generating two-dimensional  
images to be displayed on each image display plane  
based on the obtained three-dimensional shape of the  
object; and

a step of presenting a three-dimensional  
15 image of the object by displaying the generated two-  
dimensional images on each display plane,

the step of obtaining the three-  
dimensional shape of the object comprising:

20 a step of setting projection planes having  
a multi-layered structure in a virtual three-  
dimensional space;

a step of determining a reference  
viewpoint for obtaining the three-dimensional shape  
of the object;

25 a step of determining color information or  
brightness information of projection points, that  
are points on the projection planes, based on color  
information or brightness information of  
corresponding points, on the obtained images,  
30 corresponding to the projection points;

a step of determining, for each of the  
projection points overlapping when viewed from the  
reference viewpoint, an existence probability that  
is a probability that a surface of the object exists  
35 at the projection point;

the step of generating the two-dimensional  
images comprising:

-255-

converting the color information or the  
brightness information and the existence probability  
of the projection point into color information or  
brightness information and existence probability of  
5 each display point that is a point on the image  
display plane corresponding to the projection plane  
on which the projection point exists so as to  
generate the two dimensional images;

the step of presenting the three-  
10 dimensional image of the object comprising:  
displaying the color information or  
brightness information on each display point with  
brightness according to the existence probability.

15

45. The three-dimensional image display  
method as claimed in claim 44, the step of obtaining  
20 the plural images comprising:

obtaining images of the object taken from  
different viewpoints,

the step of determining the existence  
probability comprising:

25 a step of calculating correlation degrees  
among corresponding points corresponding to the  
projection points;

a step of determining, for projection  
points overlapping when viewed from the reference  
30 viewpoint, the existence probability of each  
projection point based on the correlation degree of  
each projection point.

35

46. The three-dimensional image display

-256-

method as claimed in claim 44, the step of obtaining the plural images comprising:

obtaining images of the object taken from a viewpoint by changing focusing distance,

5 the step of determining the existence probability comprising:

a step of calculating focusing degrees of the projection points from focusing degrees of corresponding points corresponding to the projection

10 points;

a step of determining, for projection points overlapping when viewed from the reference viewpoint, the existence probability of each projection point based on the focusing degree of

15 each projection point.

20 47. The three-dimensional image display method as claimed in claim 44, the step of obtaining the plural images comprising:

obtaining images of the object taken from plural viewpoints, and images of the object taken

25 from equal to one or more viewpoints among the plural viewpoints by changing focusing distance;

the step of determining the existence probability comprising:

30 a step of obtaining correlation degrees between the projection points and corresponding points on the plural images of different viewpoints;

a step of calculating focusing degrees of the projection points based on focusing degrees of the corresponding points on the images, having

35 different focusing distance, of each viewpoint; and

a step of determining, for projection points overlapping when viewed from the reference

-257-

viewpoints, the existence probability of each projection point based on the correlation degree and the focusing degree of each projection point.

5

48. A three-dimensional image display apparatus comprising:

10 an object image obtaining means for obtaining images of an object taken under different conditions;

15 a three-dimensional shape obtaining means for obtaining a three-dimensional shape of the object based on the images;

20 an observer viewpoint setting means for setting a viewpoint position from which an observer observes plural image display planes existing at different depth positions when viewed from the observer;

a two-dimensional image generation means for generating two-dimensional images to be displayed on each image display plane based on the obtained three-dimensional shape of the object; and

25 wherein the three-dimensional image display apparatus presents a three-dimensional image of the object by displaying the generated two-dimensional images on each display plane,

30 the three-dimensional shape obtaining means comprising:

a means for setting projection planes having a multi-layered structure in a virtual three-dimensional space;

35 a means for determining a reference viewpoint for obtaining the three-dimensional shape of the object;

a means for determining color information

-258-

or brightness information of projection points, that  
are points on the projection planes, based on color  
information or brightness information of  
corresponding points, on the obtained images,  
5 corresponding to the projection points;

a means for determining, for each of the  
projection points overlapping when viewed from the  
reference viewpoint, an existence probability that  
is a probability that a surface of the object exists  
10 at the projection point;

the two-dimensional image generation means  
comprising:

a means for converting the color  
information or the brightness information and the  
15 existence probability of the projection point into  
color information or brightness information and  
existence probability of each display point that is  
a point on the image display plane corresponding to  
the projection plane on which the projection point  
20 exists to generate the two dimensional images;

wherein the three-dimensional image  
display apparatus displays the color information or  
brightness information on each display point with  
brightness according to the existence probability.

25

49. The three-dimensional image display  
30 apparatus as claimed in claim 48, wherein the object  
image obtaining means is a means for obtaining  
images of the object taken from different viewpoints,  
the means for determining the existence  
probability comprising:

35 a means for calculating correlation  
degrees among corresponding points corresponding to  
the projection points;

-259-

a means for determining, for projection points overlapping when viewed from the reference viewpoint, the existence probability of each projection point based on the correlation degree of  
5 each projection point.

10            50. The three-dimensional image display apparatus as claimed in claim 48, wherein the object image obtaining means is a means for obtaining images of the object taken from a viewpoint by changing focusing distance,

15 the means for determining the existence  
probability comprising:

a means for calculating focusing degrees of the projection points from focusing degrees of corresponding points corresponding to the projection points; and

20 points, and  
a means for determining, for projection  
points overlapping when viewed from the reference  
viewpoint, the existence probability of each  
projection point based on the focusing degree of  
25 each projection point.

30            51. The three-dimensional image display  
apparatus as claimed in claim 48, wherein the object  
image obtaining means is a means for obtaining  
images of the object taken from plural viewpoints,  
and images of the object taken from equal to one or  
35 more viewpoints among the plural viewpoints by  
changing focusing distance;

the means for determining the existence

-260-

probability comprising:

a means for obtaining correlation  
degrees between the projection points and  
corresponding points on the plural images of  
5 different viewpoints;

a means for calculating focusing degrees  
of the projection points based on focusing degrees  
of the corresponding points on the images, having  
different focusing length, of each viewpoint; and

10 a means for determining, for projection  
points overlapping when viewed from the reference  
viewpoints, the existence probability of each  
projection point based on the correlation degree and  
the focusing degree of each projection point.

15

52. A three-dimensional image display  
20 program causing a computer to perform:

a step of obtaining images of an object  
taken under different conditions;

a step of obtaining a three-dimensional  
shape of the object based on the images;

25 a step of setting a viewpoint position  
from which an observer observes plural image display  
planes existing at different depth positions when  
viewed from the observer;

a step of generating two-dimensional  
30 images to be displayed on each image display plane  
based on the obtained three-dimensional shape of the  
object; and

a step of presenting a three-dimensional  
image of the object by displaying the generated two-  
35 dimensional images on each display plane,

the step of obtaining the three-  
dimensional shape of the object comprising:

-261-

a step of setting projection planes having a multi-layered structure in a virtual three-dimensional space;

5 a step of determining a reference viewpoint for obtaining the three-dimensional shape of the object;

10 a step of determining color information or brightness information of projection points, that are points on the projection planes, based on color information or brightness information of corresponding points, on the obtained images, corresponding to the projection points;

15 a step of determining, for each of the projection points overlapping when viewed from the reference viewpoint, an existence probability that is a probability that a surface of the object exists at the projection point;

the step of generating the two-dimensional images comprising:

20 a step of converting the color information or the brightness information and the existence probability of the projection point into color information or brightness information and existence probability of each display point that is a point on the image display plane corresponding to the projection plane on which the projection point exists to generate the two dimensional images;

the step of presenting the three-dimensional image of the object comprising:

30 a step of displaying the color information or brightness information on each display point with brightness according to the existence probability.

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53. A computer readable recording medium



-262-

storing the three-dimensional image generation  
program as claimed in claim 52.

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